Determination of Post-Seeding Period of Weed-Free Field Condition, on the Basis of Light Competition between Upland Crops and Weeds

By KATSUYOSHI NOGUCHI

Farm Technology Division, Tohoku National Agricultural Experiment Station
(Morioka, Iwate, 020-01 Japan)

Due to abundant rainfall and high temperature in the summer season, upland weeds flourish markedly in Japan, causing a high cost for weed control in upland fields. Nowadays herbicides are widely used in paddy fields and upland fields in Japan. Although the herbicide application is useful in stabilizing crop production and saving labor, too much use of herbicides causes several problems such as adverse effects on environment.[5,9] Therefore, there is an urgent need to establish reasonable weed control methods. The purpose of this study is to obtain fundamental data for establishing an efficient weed control method in upland fields.

Importance of light factor in competition

Crop plants grow in competition with weeds. When crop plants grow vigorously, weed growth is retarded. On the other hand, when crops lack vigor, weeds flourish. Major environmental factors in plant competition are water, light and mineral nutrients. We have to make clear what kind of environmental condition or procedure promotes the growth of crop plants and diminishes the ill effects of weeds.[1]

The present author[7] showed that competing ability of crops for weeds was related to shading caused by crop rows at and after the middle growth stage of crops. Namely, since the shading of the ground surface by crop canopies started earlier in corn and soybean fields compared with upland rice and peanut fields, the competing ability of corn and soybean for weeds was greater than that of upland rice and peanut. Iwata[2] also observed the similar results using upland rice, peanut and sorghum. The importance of light in the competition between crops and weeds was shown elsewhere.[3,4,6]

Effects of shading on growth of weeds

Effect of shading on growth of weeds was examined using 5 species, namely *Digitaria ciliaris* (Retz.) Koeler, *Cyperus microiria* Steud., *Chenopodium album* L., *Polygonum lapathifolium* L. subsp. *nodosum* (Pers.) Kitam. and *Portulaca oleracia* L.

Plant length or main-stem length of weeds increased at slight shading conditions, but it decreased by 90% shading in *D. ciliaris* and *C. microiria*, by 80–90% shading in *P. lapathifolium* and *C. album*, and by 80% shading in *P. oleracia*, respectively.[8]

As shown in Table 1, top dry weight and the number of tillers or branches of each weed decreased at all shading conditions. The decrease of top dry weight was the most remarkable in *P. oleracea* and *C. microiria* both of which showed less than 10% of the top dry weight of the control (no shading) by 84% shading. The effect of shading *D. ciliaris* and *C. album* was relatively small, showing approximately 30% of the top dry weight of the

Table 1. Effect of shading on top dry weight of weeds*

Year	Plot	*D. ciliaris*	*C. microiria*	*C. album*	*P. lapathifolium*	*P. oleracea*	
1973	1**	29.1 (58)	6.5 (23)	50.9 (55)	21.3 (33)	1.6 (13)	g/plant (%)
	2	38.0 (75)	3.6 (13)	64.7 (70)	19.2 (30)	2.2 (18)	
	3	16.0 (32)	2.3 (8)	22.0 (24)	10.1 (16)	0.5 (4)	
	4	14.3 (28)	1.1 (4)	27.4 (30)	5.2 (8)	0.4 (3)	
	5	50.6 (100)	28.6 (100)	92.3 (100)	63.8 (100)	12.6 (100)	
1974	1***	0.2 (1)	0.1 (1)	1.1 (1)	— (—)	— (—)	
	2	34.8 (100)	8.4 (100)	80.0 (100)	34.6 (100)	3.5 (100)	

* Data at the time of maturity
** 1: 75% shading during the whole growing period
2: 75% shading during 30 days after seeding
3: 84% shading during the whole growing period
4: 84% shading during 30 days after seeding
5: No shading control
*** 1: 93% shading during the whole growing period
2: No shading control

control by 84% shading. However at 93% shading, the top dry weight of each weed was reduced to less than 1.4% of that of the control. The effect of shading for *P. lapathifolium* was intermediate between these weeds.

From the above results, it was understood that weed growth was extremely inhibited by 80% or more shading in *P. oleracea* and *C. microiria*, by 80-90% shading in *P. lapathifolium*, and by 90% or more shading in *D. ciliaris* and *C. album*, respectively.

Changes of light environment in crop canopies and growth of competing weeds

Changes of light environment in crop canopies were investigated with 4 kinds of upland crops; namely upland rice, peanut, soybean and corn.

The start of shading ground surface by crop canopies after seeding occurred at the earliest time with corn, but reduction of relative light intensity under the crop was slow, and small. The start of shading by soybean was a little late as compared with that of corn, but reduction of relative light intensity proceeded rapidly, and the degree of shading was large. The start of shading was the latest in peanut, but reduction of relative light intensity was the most rapid and the degree of shading was as large as that of soybean. The characteristics of shading in upland rice were medium among these crops (Fig. 1).

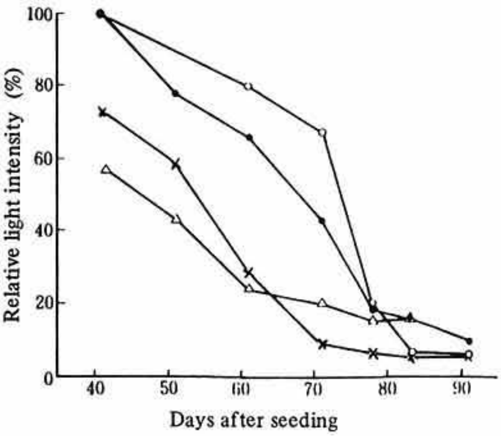

Fig. 1. Changes, with crop growth, of the relative light intensity on the ground surface at the center of inter-low space
—●— Upland rice, —○— Peant, —×— Soybean, —△— Corn

High negative correlations were found between logarithms of relative light intensity on interrow ground surface and the number of days after seeding of crops, and then the regression lines were obtained. From these regression lines, the number of days when relative light intensity is reduced to lower than 20% was estimated, that is, about 76, 78, 63 and 71 days after seeding of upland rice, peanut, soybean and corn, respectively. Similarly, the number of days when the relative light intensity is

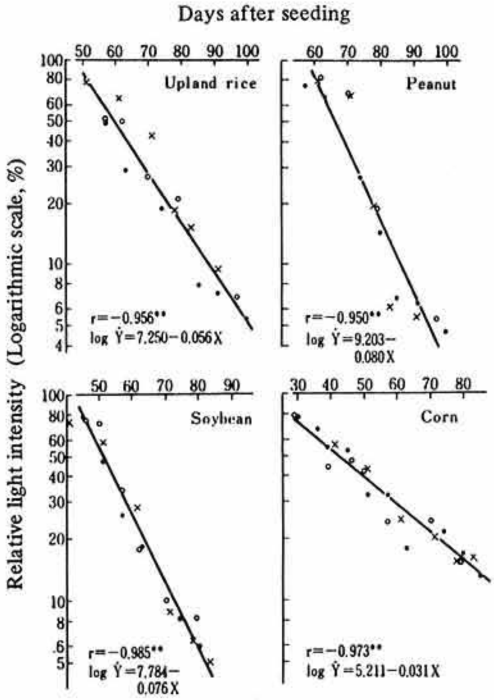

Fig. 2. Relationship between the relative light intensity on the ground surface at the center of inter-row space and the number of days after seeding
●: 1974, ○: 1975, ×: 1976
**: 1% level of significance

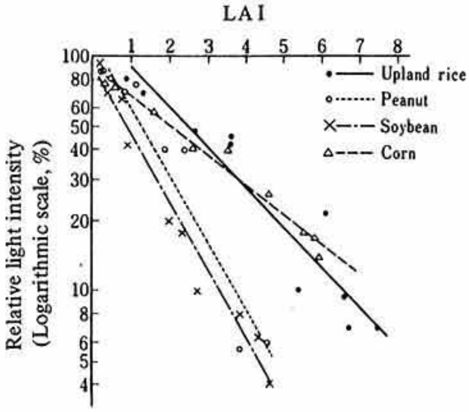

Fig. 3. Relationship between the relative light intensity on the ground surface at the center of inter-row distance and LAI
Upland rice
r =−0.946**
$\log \hat{Y}=4.895-0.391X$
Peanut
r =−0.963**
$\log \hat{Y}=4.751-0.652X$
Soybean
r =−0.985**
$\log \hat{Y}=4.494-0.665X$
Corn
r =−0.987**
$\log \hat{Y}=4.493-0.288X$

**: 1% level of significance

reduced to lower than 10% was estimated at about 89, 86 and 73 days after seeding of upland rice, peanut and soybean, respectively. Reduction to lower than 10% was not found in corn (Fig. 2).

The linear regression was obtained between LAI of crops and logarithm of relative light intensity on inter-row ground surface. From these regression lines, LAIs at the time when relative light intensity is reduced to below 20 or 10% were estimated at 4.9 or 6.6, 2.7 or 3.7, 2.3 or 3.3 and 5.2, in upland rice, peanut, soybean and corn, respectively (Fig. 3).

At the time when relative light intensity at the interrow ground surface was reduced to about 20 or 10% in the upland rice field, the interrow space upto the height of about 40 or 30 cm from ground surface showed the same relative light intensity as that at the interrow ground surface, i.e., 20 or 10%, respectively. The height of the interrow space which showed the same relative light intensity as that (20 or 10%) at the interrow ground surface was about 20 or 15 cm respectively with peanut, about 60 or 50 cm with soybean, and about 100 cm with corn (Fig. 4).

In early summer season when relative light intensity was reduced by crop canopies, plant length or main stem length of main competing weeds in this season was 1-2, 7-13, 16-28, 39-52 cm in *D. ciliaris*, 1-2, 6-12, 12-26, 20-43 cm in *C. microiria*, and 1>, 4-14, 9-25, 17-33 cm in *P. oleracea* at 10, 20, 30 and 40 days after seeding, respectively (Fig. 5).

A concept of weed-free field condition kept for a certain period

On the basis of the above results, a concept of introducing a certain period of weed-free condition into crop management system was developed, aim-

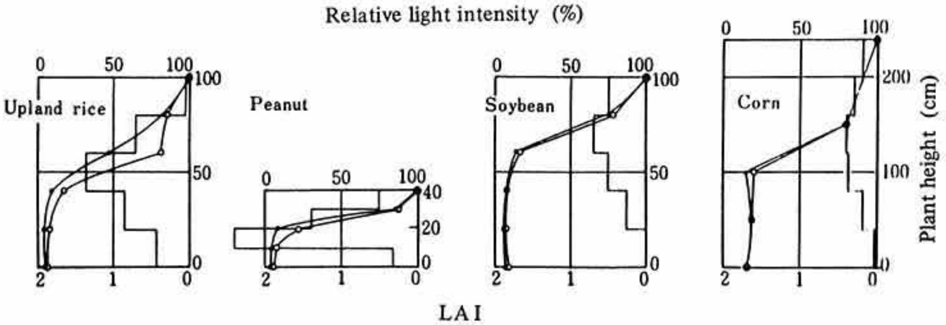

Fig. 4. Vertical distribution of LAI and changes of relative light intensity in crop canopies
Relative light intensity
—●— Between hill, —○— Between row
Results of 95 days after seeding of upland rice and peanut, and 76 days after seeding of soybean and corn.

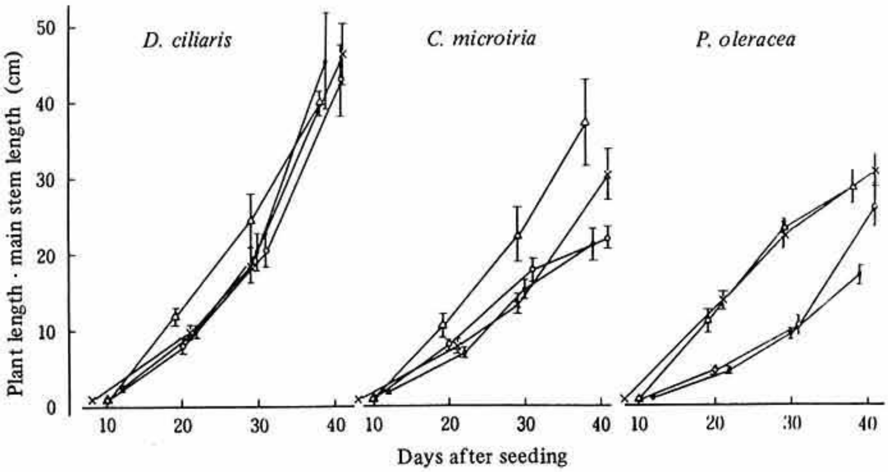

Fig. 5. Changes of plant height or main stem length of weeds
—●— June 16 seeding, —○— July 2 seeding,
—×— July 16 seeding, —△— Aug. 2 seeding
I: S.D. of the mean at 95% confidence

ing at avoiding efficiently crop yield reduction due to competing weeds.

Growth of *D. ciliaris* was greatly diminished by relative light intensity lower than 10%. The relative light intensity under the canopy of upland rice was reduced to below 10% at about 89 days after seeding, and at that time the interrow space up to the height of 30 cm was placed under the same light intensity below 10%. On the other hand, a period of 30 days or more was necessary for *D. ciliaris* to grow to about 30 cm in plant length. Therefore, a period of 59 days (89–30 dyas) of weed-free condition is theoretically required to be adopted after the seeding of upland rice in the community of upland rice and *D. ciliaris*. It was expected that growth of *D. ciliaris* which emerges after the 59th day from crop seeding will be greatly inhibited by shading of crop canopies. By the same procedure, 67 days for peanut and 33 days for soybean were estimated, respectively. Though relative light intensity was not reduced to below 10% in the corn field, a period less than 30 days was estimated from growth characteristics of corn as the period for the weed-free condition. The period for the weed-free condition was estimated to be shorter in the community consisting of crops and *P. oleracea* or *C. microiria*, because weed growth was greatly diminished at the condition of relative light intensity below 20%.

Then, an experiment on competition between 4 upland crops and weeds was conducted for the purpose of verifying the above-proposed theoretical concept on the adoption of a certain period of weed-free field condition into crop management systems.

As shown in Fig. 6, the experimental fields of upland rice, peanut, soybean, and corn were treated with different number of days of weed-free condition. In upland rice and soybean plots, it was observed that the weed (*D. ciliaris*) grew beyond the canopy of the crops when no treatment was given or only 30 days of the treatment was given, although the relative light intensity under the canopy became lower than 10%. On the contrary, the weed growth was markedly suppressed by the treatment of 47 or 58 days of weed-free condition: the weed was not able to outgrow the crop canopy. In peanut plots, however, the weed outgrew the crop canopy even when the treatment of 58 days was given. As corn plants grew tall, growth of the weed was extremely suppressed, even when no treatment was given.

Growth and yield of the crops as influenced by the treatments are shown in Table 2. The yields of upland rice and soybean were reduced in the plots without the treatment (0 days) or with 30 days of

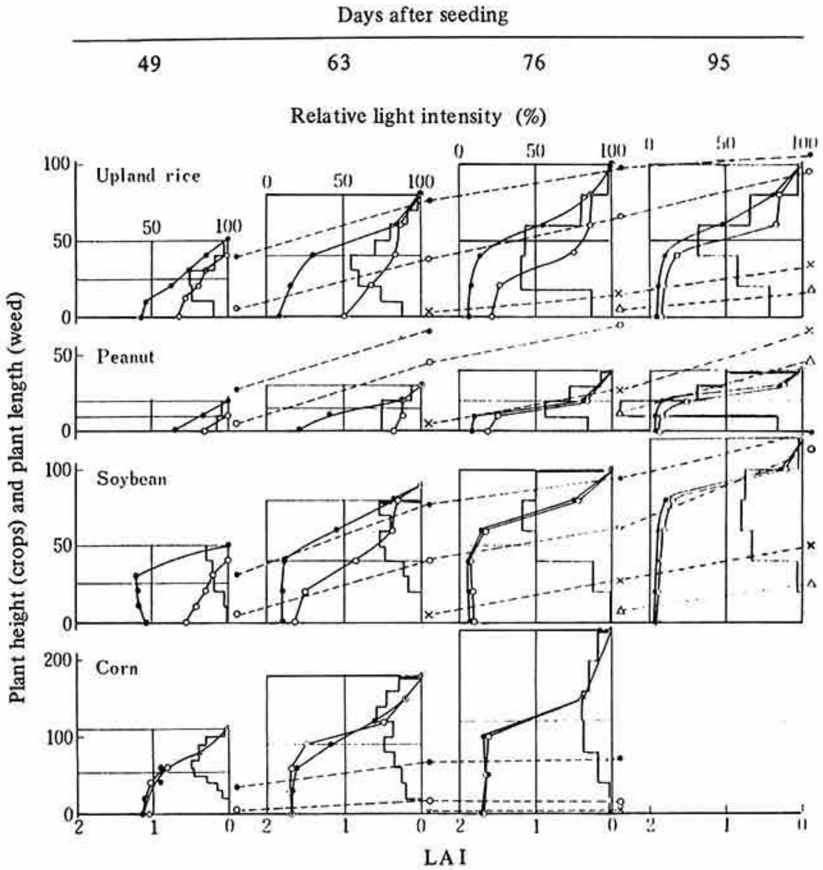

Fig. 6. Plant length of *D. ciliaris* as influenced by relative light intensity and LAI in crop canopies

Plant length of *D. ciliaris*

---●--- Plot 1, ---○--- Plot 2, ---×--- Plot 3, ---△--- Plot 4. (See Table 2)

Relative light intensity

—●— Intra-low, —○— Inter-low.

LAI ┌─┐

Table 2. Effects of different post-seeding periods of weed-free condition on crop yields

Plot	Days of weed-free condition	Upland rice			Peanut			Soybean			Corn		
		Stems and leaves	Winno-wed paddy	Total	Stems and leaves	Pods	Total	Stems	Stems	Total	Stems and leaves	Ears	Total
1	0	36	31	33	11	2	8	66	39	52	82	92	87%
2	30	89	88	86	25	4	17	80	73	76	87	94	90
3	47	98	123	104	65	10	45	95	99	96	103	97	100
4	58	112	124	114	87	67	79	98	98	98			
5	Full season	100	100	100	100	100	100	100	100	100	100	100	100
l.s.d. 0.05		6.3	11.0	6.8	16.4	18.3	14.5	11.3	13.9	12.1	15.6	n.s.	n.s.
Actual weight in plot 5 (kg/10 a)		426	217	678	402	224	626	177	209	494	691	697	1,388

the treatment, because the weed growth was not diminished greatly by crop canopies. On the contrary, yield reduction did not occur in the plots with 47 and 58 days of treatment of weed-free condition, because the weed growth was greatly suppressed by crop canopies. The yield of peanut was reduced in all plots of the treatment, as the weed grew rampantly. With corn, significant reduction of ear weight did not occur even in the plot without the treatment (0 day treatment), but weight of stem and leaves was reduced. Yield reduction of corn due to weed did not occur in the plots with 30 and 47 days of the treatment.

From the above results, the proposed hypothesis on the effectiveness of introducing a certain period of weed-free condition after seeding into the cultural management of upland crops was proved to be applicable to practical use to avoid crop yield reduction caused by competing weeds.

Establishment of weed control system including the post-seeding period of weed-free condition

By applying the concept of post-seeding period of weed-free condition, we established a weed control system for each crop, as described below:

Upland rice: Post-seeding herbicidal soil treatment + herbicidal foliar treatment 35–45 days after seeding + 1–2 times of intertillage 50–60 days after seeding

Peanut: Post-seeding herbicidal soil treatment or pre-seeding herbicidal soil incorporation treatment + herbicidal (granule) soil treatment soon after intertillage done 30–35 days after seeding + 1–2 times of intertillage 50–60 days after seeding + hand weeding at and after the 70th day from seeding

Soybean: Post-seeding herbicidal soil treatment + 1–2 times of intertillage 30–40 days after seeding

Corn: Post-seeding herbicidal soil treatment or 1–2 times of intertillage 15–25 days after seeding

References

1) Crafts, A. S.: Modern weed control. Univ. of California Press, California, 67–100 (1975).
2) Iwata, I & Takayanagi, S.: Studies on the damage to upland crops caused by weeds. I. Competition between upland crops and weeds. *Weed Res. Jpn.*, **25**, 194–199 (1980) [In Japanese with English summary].
3) Kato, T. & Sunohara, W.: Competition between main upland-crops and weeds. *Weed Res. Jpn.*, **5**, 23–33 (1966) [In Japanese].
4) Kawatei, K.: Meanings of competition in agricultural production. *Weed Res. Jpn.*, **5**, 10–15 (1966) [In Japanese].
5) Kearney, P. C.: Herbicides and environment. *Weed Res. Jpn.*, **12**, 1–6 (1971) [In Japanese].
6) Nakazawa, A.: Changes in the weed flora on upland fields by farming. *Weed Res. Jpn.*, **8**, 1–9 (1969) [In Japanese].
7) Noguchi, K., Nakayama, K. & Takabayashi, M.: Stud-

ies on competition between upland crops and weeds. I. Effects of different cropping systems on weed community. *Jpn. J. Crop Sci.*, **46**, 504-509 (1977) [In Japanese with English summary].

8) Noguchi, K. & Nakayama, K.: Studis on competition between upland crops and weeds. III. Effects of shade on growth of weeds. *Jpn. J. Crop Sci.*, **47**, 56-62 (1978) [In Japanese with English summary].

9) Yamada, T.: Fate and safe of herbicides. *Weed Res. Jpn.*, **20**, 1-7 (1975) [In Japanese].

(Received for publication, September 14, 1985)