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Watermelon cultivation with fall-planted small grain plants intercropped as cover crop

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Introduction

Recently, reduction of fertilizer and agricultural chemicals such as pesticide, fungicide and herbicide has been attempted so as to conserve the field environment and assure food safety. Polyethylene film mulch has been used for the control of soil temperature and weed suppression in the production of horticultural crops (Takakura, 1993). However, it is quite time-consuming to remove polyethylene film used as mulch in the field. Besides, waste incineration equipment is needed to burn the used polyethylene film. Organic mulches such as rice and wheat straw has attracted attention because of its ability to decompose naturally and reduce herbicides.

In the cultural weeding work, labor saving and efficiency have been means to establish a sustainable agriculture. Straw mulch is a useful and traditional technique to prevent weed growth in the past years; it is used to conserve moisture, lower surface temperature, fertilize the soil and protect the soil from rain (Partiquin, 1988). In watermelon cultivation in large-scale fields, it takes much time to cover the ground with rice, wheat or barley straw by hand. Straws laid on mulch are often blown off by a strong wind. Recently, it has become difficult to obtain rice and wheat straw since their culms are cut into small pieces for subsequent tillage at harvest time, although straws can be obtained when culms were bundled or released from harvest machine without cutting.

In the present study, fall-planted small grain plants such as wheat, barley and triticale were intercropped in advance of watermelon cultivation, and the cropping system using shading of the ground-surface by straw mulches was examined.

Materials and Methods

Watermelon was cultivated in an open field (approximately 1 ha) with organic mulch, straw mulch and living mulch of small grain plants, and weed control effect and working hours were investigated. The watermelon cultivation system in the present examination was illustrated in Fig. 1, and field work and watermelon growths were shown in Fig. 2. The following investigations were conducted on the University Farm of Niigata University, Muramatsu, Niigata Prefecture, from 1993 to 1995.

1. Wheat and barley straw mulch in interrow space

Wheat (*Triticum aestivum* L. cv. Mulchmugi for green manure) and barley (*Hordeum vulgare* L. cv. Minorimugi) were sown with the density of 4 kg/10 a, between rows in a watermelon field on October 20, 1993 (Fig.1). Elongated culms of matured plants were mowed on May 24, 1994, and turned straw mulch. After mowing of wheat and barley, light intensity of solar radiation (photon flux density) on the surface of the ground and sunshine above were measured immediately and 42 to 47 days after mowing with photon sensors (LI-190SA, LI-COR, Ltd.) and LI 1000 data logger (Meiwa Shoji Co., Ltd.) for 10 minutes; and the shading ability of wheat and barley straw mulches was also estimated. Dry weights of weed between rows covered with wheat and barley straw mulch were measured early in August.

Compound fertilizer (N: 8 kg/10 a, P_2O_5: 8 kg/10 a, K_2O: 8 kg/10 a) was added between rows in Fig.1,

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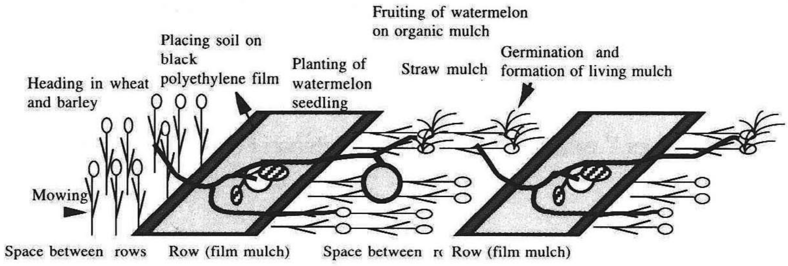

Fig. 1. Illustration of watermelon production with intercropping of wheat and barley

	1993,October	1994, April	May	June	July	Augu
Small grain plant	Seeding	heading		Mowing (May 24)	Straw mulch	Living mulch
Watermelon			Planting of seedlings (May 10)		Growing and fruiting on mulch	Harvest
Weed					Weed suppression by starw and living mulch	

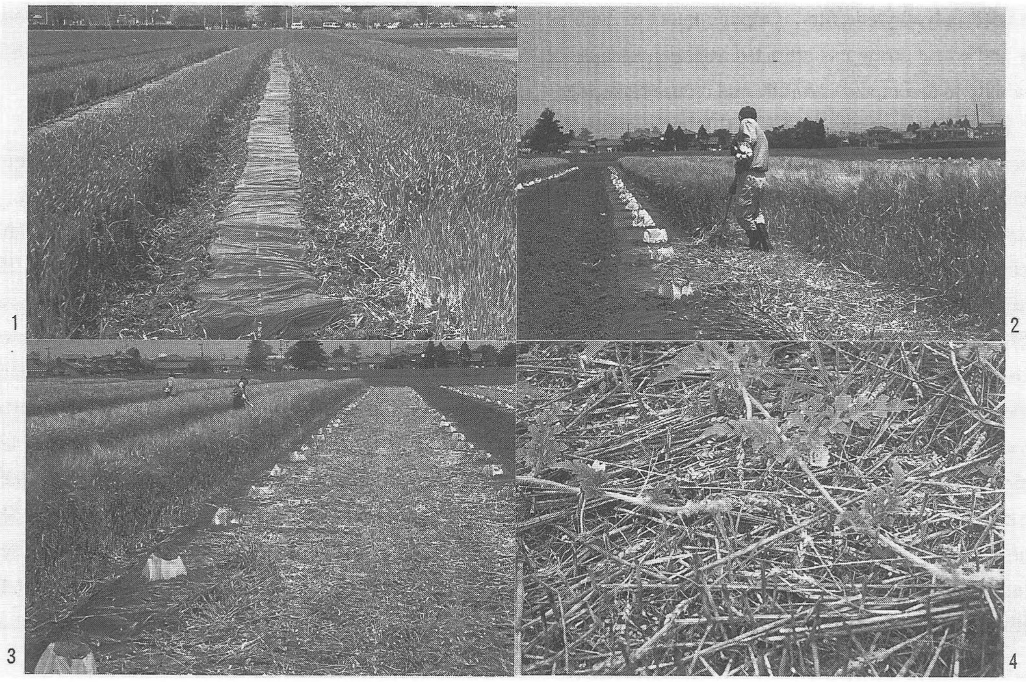

Fig. 2－1 Farm work of making straw mulch and growth of watermelon in mulch field.

1. Incorporation of wheat culm and set up watermelon row covered with black polyethylene film in early May.
2. Mowing of mature wheat by bush cutter after transplanting watermelon.
3. Set up of straw mulch between rows.
4. Elongating watermelon vines of wheat straw mulch.

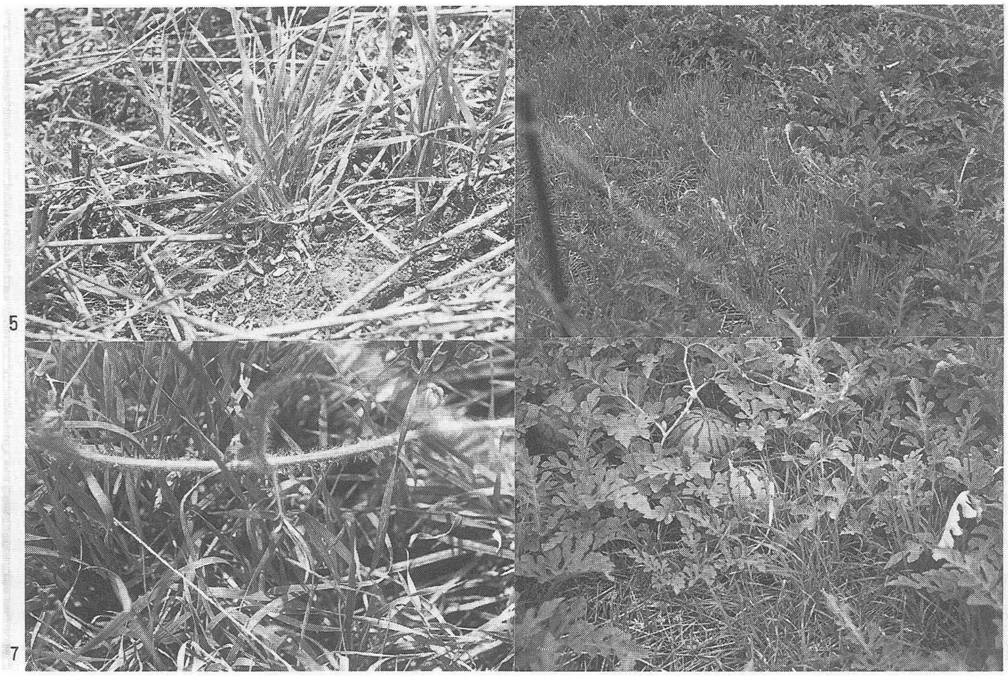

Fig. 2 − 2 Farm work of making straw mulch and growth of watermelon in mulch field.
5. Young plants germinated from the panicle of mowed culm.
6. Living mulch by leaves emerging from seeds.
7. Watermelon vines entwined around emerging leaves.
8. Watermelon production in the straw and living mulch field.

planted with wheat and barley, for basal dressing on October 20, 1993, and ammonium sulfate (N: 8 kg/10 a) for topdressing on April 7, 1994. Watermelons were cultivated as mentioned below.

Two cultivars of wheat (cvs. Koyukikomugi and Mulchmugi), barley cv. Nozominijo and triticale cv. Ryeducks were drill-sown with the density of 4 kg/10 a in interrow space in Fig.1 in October 1995. Their growth characteristics and mulch formation in the next spring were compared among the 4 fall-planted small grain plants.

2. Cultivation of watermelon

Watermelon seedlings (*Citrullus lanatus Matsum.* cv. Nisshowase) were planted on a high ridge (10 cm height, 90 cm width, 2 m distance between ridges), with a 2.5 m interval between the plants in the open field of University Farm, Niigata University, on May 10, 1994, and produced till early in August (Fig.1). High ridges planted with watermelons were supplied with chemical fertilizers (N: 6.4 kg/10 a, P_2O_5: 9.6 kg/10 a, K_2O: 8 kg/10 a) and covered with black polyethylene film (0.03 mm in thickness). The spaces between rows (Fig.1, high ridge) were covered with rice straw mulch, barley or wheat straw mulch. Watermelon vines grew over their straw mulch.

The watermelon seedlings were covered with conical-shaped paper cap for 3 weeks after transplanting. Each plant had a main stem and put out 3 lateral vines. The watermelons were harvested early in August. In 1995, watermelon was planted on May 15 and grown as the same way as in 1994.

3. Working hours

Working hours laying straw mulch and weeding between rows in the watermelon field were recorded. The working hour and yield of watermelon are change-

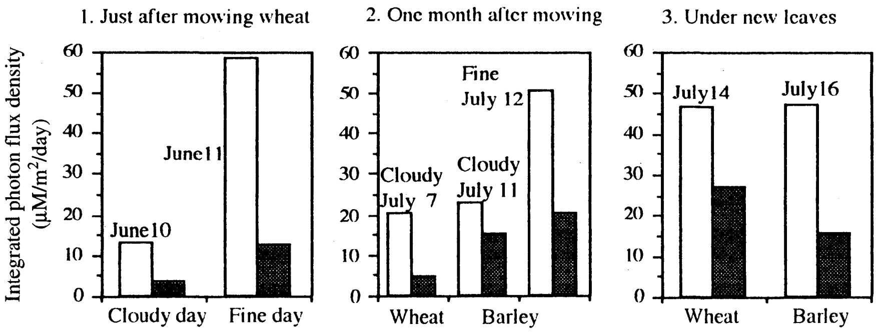

Fig. 3 Decrease of photon flux density at ground-surface of watermelon field by wheat and barley and their organic mulch in 1994.
□ Solar radiation ■ Ground surfac

able by weather condition because of production in the large-scale field. They were compared between intercropping system (1988-1994) and conventional system (1985-1987), in which straw was spread by hand, by the working data recorded in Niigata University Farm.

Results

1. Shading of ground surface under intercropped wheat and barley and their straw mulch in 1994

Before mowing the wheat and barley, the photon flux density of ground surface under wheat culms was less than 10 $\mu M/m^2 \cdot day$, even on a fine day, and the light transmission rate of ground surface to solar radiation above was 23%. The rate was 20% in barley plants. Few weeds grew in the communities of wheat and barley plants.

Just after mowing culms developed, the photon flux density of ground surface under wheat straw mulch was less than 3 $\mu M/m^2 \cdot day$ on a cloudy day and less than 14 $\mu M/m^2 \cdot day$ on a fine day. Light transmission rate to the ground surface was approximately 20% (Fig. 3). The same results were obtained for barley straw mulch.

One month after mowing the culm, the photon flux density of ground surface under wheat straw mulch was less than 4 $\mu M/m^2 \cdot day$ on a cloudy day. The density reached 14 $\mu M/m^2 \cdot day$ on a cloudy day and 20 $\mu M/m^2 \cdot day$ on a fine day under barley straw mulch, with the light transmission rate ranging 40-61%. The barley straw decomposed easier than wheat straw.

Germination from the seeds ripened on the panicle of the mowed culm began late in June, and new leaves developed above the ground. The average width of a new leaf was 8.0 mm in wheat and 12.3 mm in barley (Table 1). Photon flux density under the new leaves was 27 $\mu M/m^2 \cdot day$ in wheat and 15 $\mu M/m^2 \cdot day$ in barley. The shading ability of new leaves in barley was greater than in wheat because of its broader leaf.

Dry weight of weed emerged until July was 980 g/m^2 between rows without straw mulch (Fig. 4). It

Table 1 Comparison of number of tillers and width of leaf developed from seed germination between wheat and barley previously sown in autumn.

Plants	Cultivar	No. of tillers		Leaf width (mm)	
		Ave.	SE	Ave.	SE
Wheat	Mulchmugi	7.0	0.3	8.0	0.3
Barley	Minorimugi	3.4	0.2	12.3	0.2

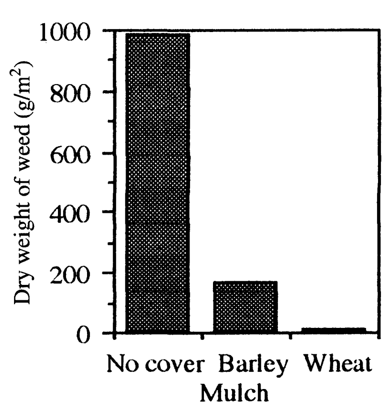

Fig. 4 Effect of straw mulch on weed control from transplanting (May 10) to end of July in 1994.

decreased to 180 g/m^2 in barley straw mulch and 20 g/m^2 in wheat straw mulch.

Watermelon vines spread out on the wheat straw and living mulch, young plants emerging from the matured grains of wheat mowed, and became twisted with the leaves of living mulch. Watermelon fruited on the straw and living mulch.

2. Growth characteristics of 4 intercropped fall-planted small grain plants the next spring (1995)

There was a difference in growth among 4 fall-planted small grain plants intercropped (Table 2). The culm of every small grain plant began to elongate in May, developing to 151 cm in triticale and approximately 100 cm in wheat and barley. Culm width of triticale was largest (5.5 mm) and barley followed (4.3 mm) at maturity. A large number of thin culms (3.2-3.3 mm) were obtained in wheat, especially in cv. Mulchmugi (1,332/m^2), compared with barley (644/m^2) and triticale (577/m^2). At mowing on May 24, dry weight of culm of triticale was largest (3,385 g/m^2). On the other hand, those of mulchmugi, koyukikomugi and barley were 1,676, 1,121 and 1,410 g/m^2, respectively. The ground surface was densely covered with wheat straw densely, especially with cv. mulchmugi, while straws of barley and triticale covered the ground surface sparsely.

Germination from seeds ripened on the panicle of the mowed culm occurred in wheat and barley in July, and living mulch was formed. Living mulch of wheat was lasted until the middle of August, the time of watermelon harvest. Barley leaves died in mid or late in July. Triticale showed no seed germination but the lateral shoot developed from stubble. Lateral shoots lifted the watermelon vines and obstructed the fruiting.

3. Comparison of working hours

As for the mulching and weeding in watermelon cultivation, it took 5.2 hours to lay straws in the intercropping system and 13.8 hours in the conventional system, in which rice straw was carried to the field and spread by hand (Table 3). In the intercropping system, cultivation of wheat took 8.1 hours, including sowing, topdressing of fertilizer and mowing. Weeding work took 4.7 hours in the conventional system, while no weeding was necessary between rows in the intercropping system. Total working hours on mulching and weeding was 18.5 hours in the conventional system and decreased to 13.3 hours in the intercropping system.

There was no definite difference in yield of watermelon between the intercropping system (1,065

Table 2 Growth characteristics of 4 fall-planted small grain plants.

Crops	Cultivar	Plant length (cm)	Culm Width* (mm)	Culm Number (/m^2)	Culm Dry weight (g/m^2)	Maturity
Wheat	Koyukikomugi	93	3.2	1098	1121	May 28
Wheat	Mulchmugi	106	3.3	1332	1676	May 28
Triticale	Ryeducks	151	5.5	577	3385	June 20
Barley	Nozominijo	96	4.3	644	1410	May 20

* Center portion was measred as width.

Table 3 Comparison of working hours for straw mulching and weeding in interrow space between conventional and intercropping in watermelon production. *

Mulching method	Working hours (hours/10 a)				Yield (kg/10 a)	
	Laying of straw	Wheat cultivation	Weeding	Total	Ave.	S.E.
Conventional	13.8	0	4.7	18.5	1147	428
Intercropping	5.2	8.1	0	13.3	1065	171

* Average data of 3 years (1985-1987) in conventional straw mulching and that of 7 years (1988-1994) in intercropping straw mulching.

kg/10 a) and the conventional system (1,147 kg/10 a) (Table 3).

Discussion

Intercropping of wheat has been attempted in the food crop and vegetable field in Japan (Kirihara, 1984). The main purpose of the intercropping was to increase productivity and use the agricultural field efficiently. In the intercropping and organic mulch system presented here, small grain plants were sown between rows in advance of watermelon cultivation, and watermelons were grown on the straw and living mulch the next year. This system was characterized by no weeding work due to the suppression of small grain plants. Wheat and barley intercropped support the growth of watermelon, but any grains are not harvested.

In some crops (smoother crops), weeds are effectively suppressed by the shading of the ground surface and their allelo chemicals (Ito, 1993; Putnam and DeFrank, 1983; Barns and Putnam, 1983; Mwaja et al., 1995). They include rye, barley, sorghum, corn, foxtail millet, sunflower, buckwheat, clover and foliage soybean. Emergence of upland weeds is usually suppressed under less than 10% relative light intensity (Noguchi, 1986). In the present study, barley and wheat plants and their straw mulches suppressed the light intensity at the ground surface and served to decrease weed growth. However, there was a difference in the ability to shade the ground surface between wheat and barley sown in previous year because of the difference in their botanical characteristics such as the number and toughness of culm and the size of new leaves developed from the seed germination. For maintaining the low light-intensity on the ground surface for a long period, cv. Mulchmugi, the wheat cultivar for green manure with a number of tillers, is a promising material.

Leaving a straw mulch in no-tillage field gave the highest degree of weed control (Worsham, 1995). With rye, this approach has been particularly effective since rye has a high biomass production of shoots and roots, winter hardiness, and phytotoxicity of residues (Putnam and DeFank, 1983; Barnes et al., 1986; Worsham, 1995; Shilling et al., 1986). Triticale has a high biomass as well as rye, but did not fit the intercropping system in watermelon cultivation because triticale matured later than wheat and barley, and elongation of watermelon vines was obstructed by the lateral shoots developing from the stubble after mowing culms.

Cover crop mulch systems often use fall-planted small grains or legumes to produce residues for spring-planted vegetables. These systems lead to modification of the environment of the crop production, affecting pest populations and vegetable crop yield (Mwaja and Masiunas, 1996). Generally, cover crop mulch systems decrease water evaporation and increase infiltration, resulting in greater soil moisture (Knavel and Herron, 1986; Schonbeck et al., 1993; Okazaki et al., 1994). Germination from seeds ripened on the panicle of the culms in wheat and barley mowed was induced by the moisture conditions near the ground surface, and as a result of it, young seedlings of them turned into living mulch.

It should be noted that the intercropped smoother crops could reduce the yields of the main crop species when the competition for water and nutrients is strong (Kurtz et al., 1952). In the present study, no decrease in watermelon yield was observed. This may be due to the facts that the rows of watermelon were tilled and covered with black polyethylene film, and the root of watermelon mainly grew in the row, resulting in little competition between the watermelon and the small grain plants.

The intercropping system used in this study needed no weeding between rows. This is very important because hand weeding is physically exhausting, and recently farmers have to decrease the use of herbicides for environmental conservation. Omission of the straw spreading work will lead to more efficient agricultural work. In the conventional system in watermelon cultivation in the open field, it took much time to lay straw by hand and the process had to be repeated whenever straw was blown off by strong winds. The intercropping system made it unnecessary to collect straw from another small grain field and carry it to the vegetable field.

There are some problems to overcome in the intercropping and organic mulch system in watermelon cultivation. First, mowing is done with a bush cutter, and it is heavy work because of the vibration of the bush cutter. It is necessary to introduce a mower when this system is to be applied to large-scale field. Second, weeds grew from the soil placed on the black polyethylene film, which is used to cover the watermelon seedlings, where the straw did not provide cover.

Mentioned above, intercropping and organic mulch system will be effective for crop production because decrease of weeding labor and improvements of mulching work. Difference in weed interference among winter wheat cultivars have been observed in farmer field (Wicks et al., 1986). It is necessary to select more suitable small grain plant for cropping type of main crops.

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Abstract

Wheat (*Triticum aestivum* L. cv. Mulchmugi) and barley (*Hordeum vulgare* L. cv. Minorimugi) were introduced in watermelon production for weed control, not seed production. To examine the weed control-effect of wheat and barley between rows of a watermelon field, they were sown in October, 1993, with the seeding rate of 4 kg/10a. Elongated culms were mowed early in June, 1994, and turned into straw mulch. Light intensity (photon flux density) on the surface of the ground was suppressed by straw mulch of wheat and barley. Suppression of light intensity in wheat straw mulch 1 month after mowing was greater than that of barley because of the large biomass and its toughness. Matured seeds of the mowed culm germinated late in June, and new leaves developed above ground. Suppression of light intensity by new leaves of barley plants was more than that in wheat, and photon flux density on the surface of the ground was reduced to 30% of solar radiation. Weed quantity between rows was effectively reduced, especially by wheat straw mulch. Ground surface cover with triticale (x *Triticosecale* Wittmack cv. Ryeducks) was sparse because of fewer numbers of culms. Triticale was not suitable for the plant material of straw mulch in watermelon cultivation since the new shoots developed from the stubble after mowing and lifted the watermelon vines up. Intercropping system decreased the working hours for laying of straws and weedingin the field, and consequently led to labor saving.

Key words

weed prevention, wheat, barley, straw mulch, living mulch, light intensity, watermelon

カバークロップとしてのムギ類を利用したスイカ露地栽培

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要　旨

1993年10月にスイカ作付予定圃場の畝間にコムギとオオムギを4kg/10aの密度で播種し，1994年春スイカ定植後にムギ類を刈り倒し，麦稈マルチを形成した．これらのムギ類の刈り倒された稈の先端に着生した成熟粒より発芽が認められ，茎葉が成長してリビングマルチが形成された．麦稈マルチとリビングマルチは土壌表面へ到達する光量子を抑制し，雑草の発生を抑制した．雑草抑制の効果はオオムギに比べ，コムギの方が大きかった．1994年10月にコムギ2品種，オオムギおよびライコムギを翌年のスイカ圃場の畝間に 4 kg/10aの密度で播種して，1995年6月に刈り倒して，マルチ素材としての植物特性を評価した．ムギの種類により麦稈量や発生した新葉の大きさ等が異なった．コムギは細い分けつが多数発生するため密なマルチが形成された．オオムギの葉は大きく，地表面を効果的に遮光したが，リビングマルチはコムギの方が長く維持された．ライコムギでは刈り倒し後に新たな分げつ芽が発生し，スイカ果実の成長を阻害した．間作ムギ体系は稲藁を搬入して敷藁とする従来の作業体系に比べ，圃場への稲藁や麦稈の搬入が不要となり，除草作業もなくなる等，省力的な作業体系と考えられた．

キーワード

雑草抑制，コムギ，オオムギ，麦稈マルチ
リビングマルチ，光強度，スイカ

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