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AN ASSESSING OF GRASSHOPPER CONSUMPTION *(ORTHOPTERA: ACRIDIDAE)* ON THE PRIMARY PRODUCTION OF PYRENEAN PASTURES ABOVE TIMBERLINE[1]

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SUMMARY.—A method of assessing grasshopper consumption (Orthoptera: Acrididae) *in grazed grasslands above timberline, at the Central Western Pyrenees is tested. The method is based on exclusions used under seminatural conditions. Daily variation in consumption is related to grasshopper microenvironmental temperature. With a diurnal average temperature of 21º C, grasshoppers consume daily their body weight in grass. Comparison between grasshopper and cattle consumption is also done. In 1987 the density of grasshoppers was so high that their consumption was similar to or larger than that of cattle. In ungrazed grasslands Acrididae may be important in the acceleration of nutrient recycling.*

RESUMEN.—Estimación del consumo por los saltamontes (Orthoptera: Acrididae) *de la producción primaria de pastos supraforestales pirenaicos. Se propone un método de estima de la producción primaria consumida por los saltamontes* (Orthoptera: Acrididae) *en pastos supraforestales del Pirineo centrooccidental. Se utilizan exclusiones en condiciones seminaturales y se relaciona la variación del consumo con la temperatura del microambiente en que viven los saltamontes. Sobre una temperatura media diurna de 21º C, los saltamontes consumen cotidianamente su propio peso. Se compara el consumo de los saltamontes con el ganado con manejo tradicional. El consumo de los saltamontes es similar o superior en años de elevadas densidades de saltamontes, como 1987. En prados no pastados los acrídidos son importantes en el reciclaje de nutrientes.*

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RÉSUMÉ.—Une estimation de l'ingestion par les criquets (Orthoptera: Acrididae) *sur la production primaire des pâturages Pyrénéens au dessus de la limite de la fòret. On propose une méthode pour estimer la production primaire ingerée par les criquets* (Orthoptera: Acrididae) *dans les pâturages suprafo-restiers des Pyrénées centrales- occidentales. On utilise des enclosures ayant des conditions séminaturelles, et on met en rapport la variation de l'ingestion avec la témperature du microenvironnement où les criquets vivent. Avec une témperature moyenne de 21º C ils consomment son poids en herbe chaque jour. La consommation de la part des criquets est comparée avec celle du bétail; la première est équale ou plus grande que l'autre les années de grande densité de population des acridiens, par example, 1987. Dans les pâturages non pâturés les criquets jouent un ròle important dans le recyclage des nutrients.*

Keywords: *Grasshoppers consumption, primary production, Thermic ecology, cattle consumption, Pyrenees.*

Consumption of phytophagous Orthoptera has been studied in different terrestrial ecosystems, principally in grasslands (GYLLENBERG, 1969; ANDRZEJEWSKA and WOJCIK, 1970; BAILEY and RIEGERT, 1973; WHITE, 1974), fields (WIEGERT, 1965) or heatlands (GUEGUEN and DELAUNAY, 1980).

In Pyrenean pastures above timberline they are the primary invertebrate consumers with greatest biomass (ISERN and PEDROCCHI, 1988). In the areas without forest, which have been kept as pastures by human and cattle influence —approximately between 1600 and 2000 m of altitude— the density of Acrididae propulations has considerable interannual variations. They always have the highest arthropod biomass. Species are univoltine. Grasshoppers pass the unfavourable season as eggs; hatching happens in May or June and adults may live until November (ISERN and PEDROCCHI, 1987). During the summer these areas are grazed by cattle.

In this paper we discuss the importance of grasshoppers as consumers of plant biomass in pastures above timberline, testing a method based on exclusions used under seminatural conditions.

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1. Methods

This study has been done in pastures above timberline in Aísa and Borau (Pyrenees, Huesca, Spain) in August of 1987 and 1988. Six different plots of *Nardion* communities have been selected between 1600 and 2100 m of altitude (Fig. 1).

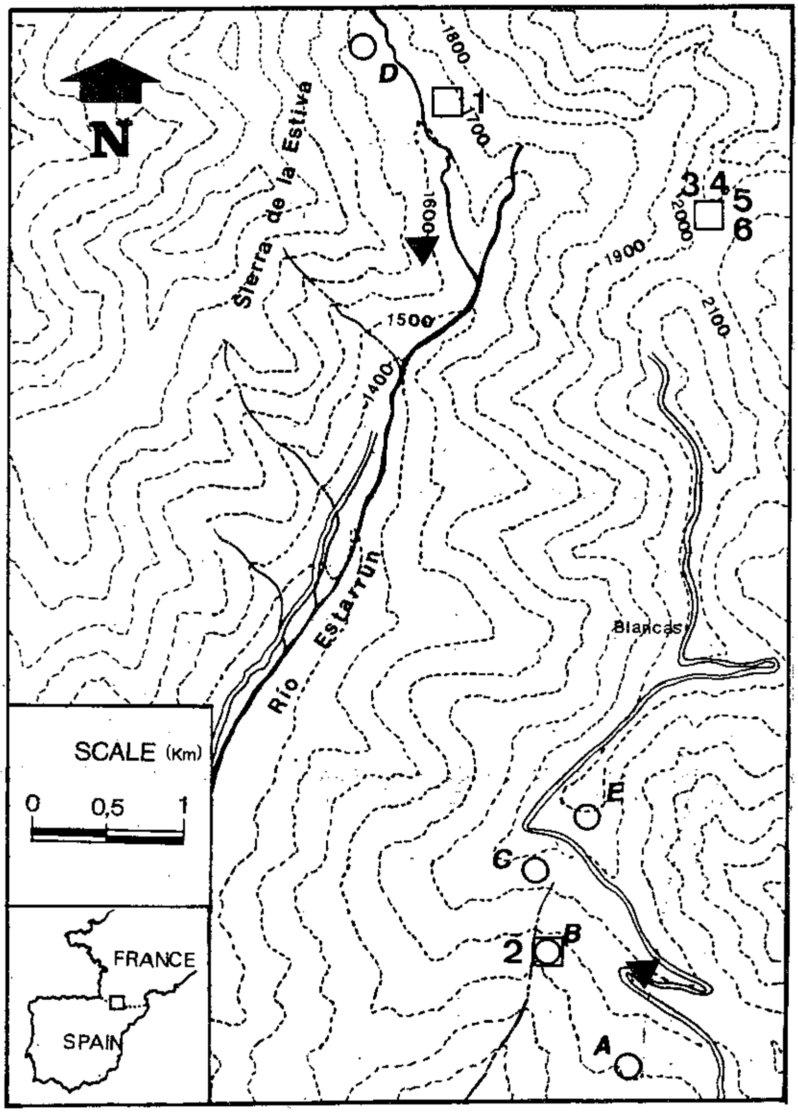

Figure 1. — Site of study area, in Aísa and Borau valleys (Huesca, Spain). In squares, plots where the consumption experiments have been done (1-6). In circles, plots where monthly consumption has been assessed (A-E). In triangles the nearest weather stations. *(Localización de la zona de estudio, en los valles de Aísa y Borau (Huesca, España). Los cuadrados indican la situación de las exclusiones de consumo (1-6). Los círculos, las parcelas donde se ha estimado el consumo mensual (A-E). Los triángulos marcan la situación de las estaciones meteorológicas próximas).*

The experience is based on the isolation of small homogeneous parts of the area of the grassland by means of exclusions. A known amount of grasshoppers —caught from the grassland surrounding them— was placed in some exclusions. We compared them with other identical exclusions where consumption was avoided. This method was used by ANDRZEJEWSKA et al. (1967), ANDRZEJEWSKA and WOJCIK (1970) and GYLLENBERG (1969).

Exclusions have been made with aluminium rods and metal frames of 1 mm, permitting free passage of air, to avoid as well as possible the microclimatic disturbances. Exclusion size, with square base and 30 cm side, has been selected from primary production studies in nearby pastures (REMON and ALVERA, 1988).

In each of the six experiments we used three exclusions with some grasshoppers (test exclusions) and three exclusions without any (control exclusions).

In each experiment the following steps have been taken:

Six exclusions were placed on an homogeneous surface of grassland (Photo 1). We introduced into three of them about 50 adult grasshoppers. This number, which surpasses real densities (Table I), has the purpose of accelerating the experiment. Possible effects of

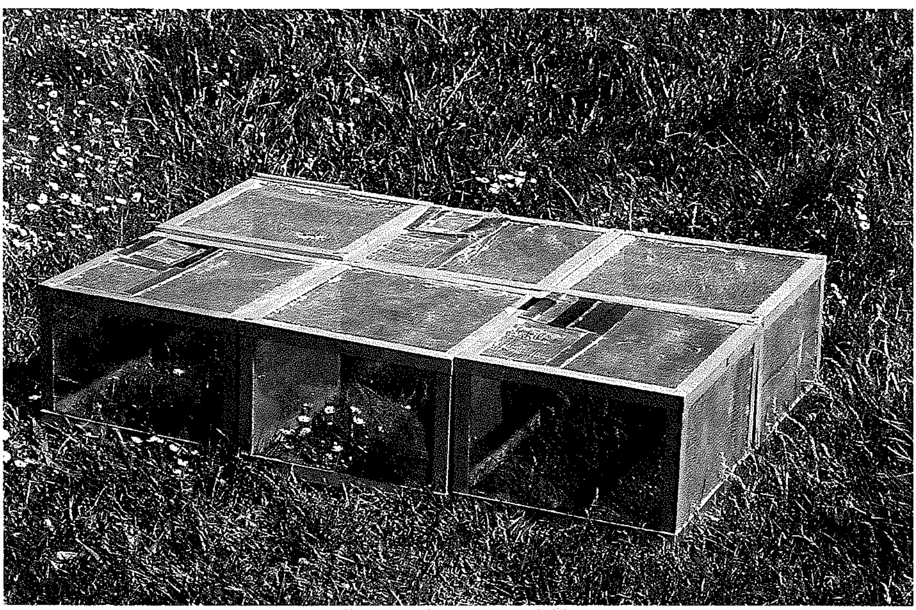

Photo 1. — Placing of consumption exclusions in a plot during the experiments with grasshoppers. *(Disposición de las exclusiones de consumo en una parcela durante los experimentos con saltamontes).*

overcrowding, such as the reduction of consumption (ANDRZEJEWSKA and WOJCIK, 1970), have not been considered.

TABLE I

	DENSITY (ind m-2)		BIOMASS (g dry weight m-2)	
	Ist	2nd	Ist	2nd
A	19.8	14.2	1.07	0.64
B	19.2	10.2	0.94	0.48
C	43.4	22.0	2.41	0.95
D	18.6	4.2	0.95	0.18
E	28.4	19.6	2.24	1.50

Table I. — Densities and biomasses of grasshoppers *(Orthoptera: Acrididae)* in August 1987 (first and second fortnight). Data of four *Nardion* communities (A-D) and one community with *Festuca eskia* (E) in pastures above timberline in Borau and Aísa (Huesca, Spain). (Densidades y biomasas de saltamontes *(Orthoptera: Acrididae)* en agosto de 1987 (primera y segunda quincena). Datos de cuatro comunidades de *Nardion* (A-D) y una comunidad con *Festuca eskia* (E) en los pastos supraforestales de Borau y Aísa (Huesca, España).

Then we let 24 hours pass. During that time we controlled periodically the temperature in the grass, recording each hour from 6 a.m. until 19 p.m. (solar hour).

When the experimental period had passed, we killed the grasshoppers and removed the exclusions. We carried each of the insect samples and each of the grass samples resulting from the reaping in the six exclusions, to the laboratory. Dry weight (80º C) was done on all the samples in order to know the biomasses.

In each experiment we calculated the plant average biomass from the results of control exclusions. Losses in primary production caused by grasshoppers were estimated, substracting from the plant biomass average each of the plant biomasses found in the test exclusions.

Results are expressed in relation to the grasshopper biomass (consuming ratio: consumption per unit of body weight). An average of consuming ratio was calculated for each experiment.

In order to know statistical significance, standard deviation (s) and standard error (D) were calculated. D is definited as:

$$D = 1/\bar{x} \qquad \sqrt{s^2/n \ t\alpha}$$

Not accepted if $D > 0.40$ (MONTES and RAMIREZ, 1978).

Plant biomass consumed by grasshoppers under seminatural conditions was related to the temperature in the grass, recorded during the experiments.

Using unpublished data of grasshopper densities and biomasses taken with biocenometre in four *Nardion* communities and one *Festuca eskia* community, we assessed the total consumption during a month, August 1987. In order to do this, we had to calculate the correlation between the temperature recorded in the grass during the experiments and climatic data from thermographers placed in nearby weather stations (Fig. 1).

2. Results

Table II shows the results of experiments with consumption exclusions.

TABLE II

	1	2	3	4	5	6
Date (days (August.) year)						
	18/19.87	7/8.88	12/13.88	20/21.88	23/24.88	27/28.88
Average plant biomass (g m-2)						
C	118.89	234.44	281.44	185.00	161.00	103.78
n	3	3	3	3	2	2
s.......	1.06	0.82	0.64	1.12	0.06	1.59
D	0.11	0.04	0.03	0.08	0.01	0.24
T	86.89	206.11	229.11	166.33	147.11	79.11
n	3	3	3	3	2	2
s.......	1.80	0.73	0.49	0.64	1.05	0.81
D	0.27	0.05	0.03	0.05	0.11	0.16
Average grasshopper biomass (g ind-2)						
	0.0414	0.0442	0.0593	0.0479	0.0582	0.0581
n	147	150	147	155	98	95
Average consuming ratio						
	1.5456	1.1531	1.4404	0.6734	0.4190	1.3121
n	3	3	3	3	2	2
s.......	1.07	0.31	0.34	0.23	0.31	0.05
D	0.80*	0.31	0.27	0.39	1.06*	0.06

* Not accepted if D > 0.40.

Table II. — Average of plant biomass from the control exclusions (C) and from the consumption tests (T) with grasshoppers; average biomass of grasshoppers and consuming ratio (dry weight of consumed grass per unit of body weight of grasshoppers) in each experiment (1-6) (see text). (Biomasa vegetal media en las exclusiones control (C) y en las pruebas de consumo (T) de saltamontes; biomasa media de los saltamontes y relación de consumo (peso seco de hierba consumida por unidad de peso de saltamontes) en cada experimento (1-6) (ver texto)).

The average of plant biomass in the communities of *Nardion* varies between 104 and 281 g m-2. These values are similar to data obtained by REMON and ALVERA (1988) in plant ecology studies of pastures placed near our plots, between 97 and 208 g m-2.

The average of remaining plant biomass —after 24 hours of maintaining a density of about 555 grasshoppers per square metre— varies between 79 and 229 g m-2.

We accept as significant three exclusions of 0.09 m^2 in order to know plant biomass (D between 0.01 and 0.11) and also in order to know consumption (D between 0.03 and 0.27).

Consuming ratio calculated in each experiment had the following values: 0.42, 0.67, 1.15, 1.31, 1.44 y 1.55. In the extreme values (experiments 1 and 5) the significance is very low (D higher than 0.4).

The approximate dry body weight of one adult grasshopper in the studied pastures is 0.05 g. Acording to the consuming ratio, its assessed consumption would vary between 0.02 and 0.08 g of grass (dry weight) per day.

Those differences in the consuming ratio observed in the experiments depend on the feeding activity of grasshoppers, which is related to the temperature (WHITE, 1974).

Table III shows maximum, minimum and average temperature values (n = 14, from 6 a.m. until 19 p.m. (s.h.)) in the grass during the experiments.

The highest average temperature (26º C) corresponds to a consuming ratio of 1.31. The lowest average temperature (16.5º C), to 0.42.

Figure 2 shows the variation in average diurnal temperature of experimental values of consuming ratio.

Consuming ratio increases with temperature. At 21º C the relation approaches one. The maximum is placed between 25 and 26º C. With higher temperatures, consuming ratio decreases. This upper threshold

TABLE III

	1	2	3	4	5	6
Max.	37.4 (12 h)	33.2 (16 h)	36.8 (12 h)	35.0 (13 h)	29.9 (13 h)	43.5 (12 h)
Min.	6.4 (6 h)	8.5 (6 h)	9.0 (19 h)	3.0 (19 h)	1.0 (6 h)	11.0 (6 h)
Average	25.9	22.4	23.9	17.8	16.5	26.3

Table III. — Temperature in the grass (º C) recorded during the consumption experiments (1-6). Values were recorded each hour between 6 a.m. and 19 p.m. (solar hour): Maximal, minimal and average values during this period (n = 14). (Temperatura (º C) entre la hierba registrada durante los experimentos de consumo (1-6). La temperatura se anotó cada hora de las 6 a las 19 h (h.s.): Valores máximos, mínimos y medios durante este período (n = 14)).

is interpreted as an increase of the inactivity period during the day because of high temperatures. Lower threshold can not be detected with this experiment.

TABLE IV

	Aver. biomass (g m-2)	Max.	Aver.	Min.
A	0.8526	40.97	32.51	24.05
B	0.7077	34.01	26.99	19.96
C	1.6816	80.80	64.12	47.44
D	0.5690	27.34	21.70	24.88
E	1.8753	90.11	71.51	52.91

Table IV. — Assessing of Acrididae biomass for August 1987, from data of table I. Estimate value of the consumed plant biomass; consuming ratio applied was 1.23 ± 0.32, corresponding to the average diurnal temperature in the grass, 22.8º C. (Biomasa de acrídidos consumidores estimada para el mes de agosto de 1987, a partir de los datos de la tabla I. Estima de la biomasa vegetal consumida; se ha aplicado la relación de consumo 1.23 ± 0.32, que corresponde a la temperatura media diurna entre la hierba, 22.8º C).

2.1. *Monthly consumption by grasshoppers*

In order to assess the grasshopper consumption in pastures we calculate the consuming ratio for August of 1987. We used the average diurnal temperature, estimate from metheorological data recorded from the weather stations (Table V).

TABLE V

Day	T	Day	T	Day	T	Day	T
1	19.8	10	16.1	19	22.7	28	13.9
2	22.6	11	19.1	20	23.9	29	16.9
3	22.8	12	22.7	21	22.9	30	17.1
4	21.0	13	25.0	22	24.3	31	16.0
5	19.9	14	26.1	23	11.6		
6	13.6	15	26.7	24	5.8	Average T	
7	13.2	16	25.7	25	8.7	x = 18.3	
8	14.6	17	14.1	26	13.6	y = 22.8	
9	16.6	18	18.4	27	11.2		

Table V. — Average of diurnal temperature (from 6 a.m. until 19 p.m., n = 14) during August 1987: values recorded in thermographers (x), monthly average and transformed values of temperature in the grass (y). Regression line is: y = 1.60 x - 6.48; n = 82; r = 0.7434. (Temperatura media diurna (de 6 a 19 h. n = 14) durante agosto de 1987: valores registrados en los termógrafos (x), media mensual y valores transformados en temperatura entre la hierba (y). La recta de regresión es: y = 1.60 x - 6.48; n = 82; r = 0.7434).

The average diurnal temperature in August of 1987 at the weather stations was 18.3º C.

The regression line that converts temperature in the weather stations (x) into temperature in the grass (y) is:

$$y = 1.60\,x - 6.46;\ n = 82;\ r = 0.7431$$

Therefore, the assessing of average diurnal temperature in that month in the microenvironment where the grasshoppers lived was 22.8º C. Starting from the graphics (Fig. 2), consuming ratio was 1.23 ± 0.32.

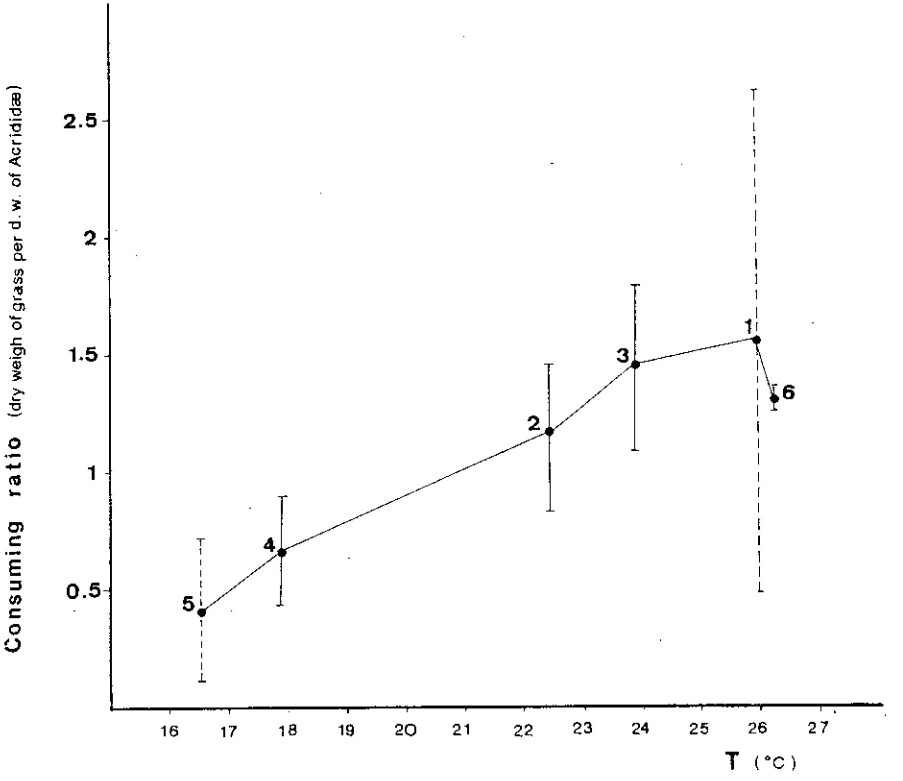

Figure 2. — Variation of consuming ratio of grasshoppers *(Orthoptera: Acrididae)* with diurnal average temperature. Vertical lines indicate the range of variation in each of six temperatures. *(Relación de consumo de los saltamontes (Orthoptera: Acrididae) en función de la temperatura media diurna. Las líneas verticales indican el rango de variación en cada una de las seis temperaturas).*

Table I shows densities and biomasses of Acrididae in four plots in *Nardion* communities and one plot placed in a community with *Festuca eskia,* also in the pastures above timberline, during August of 1987 (ISERN, unpublished).

In the *Nardion* communities, densities vary from 4.2 until 43.4 grasshoppers m-2. Biomasses do it from 0.18 until 2.41 g m-2. In *Festuca* densities are 28.4 and 19.6 grasshoppers m-2, and biomasses are 2.24 and 1.50 g m-2.

Table IV shows the average of grasshopper biomass in August, for the five plots, estimated with data from table I. Values are the following: 0.69, 0.71, 1.68, 0.57 and 1.87 g m-2. By means of the August consuming ratio, we assessed that the averages of consumption during all the month in the four communities of *Nardion* were the following: 32.51, 26.99, 64.12 and 21.70 g m-2.

Observations recorded in communities with *Festuca eskia* allows us to suppose that consuming ratio in Acrididae is similar to the *Nardion.* So we estimate that the average consumption in our plot during August was 71.51 g m-2.

Festuca eskia forms a plant community which neither cows nor sheep use to graze; it may be grazed in spring in the few places where horses and goats still exist.

2.2. *Consumption by cattle*

In order to make a comparison, we calculated the plant biomass consumed by cows —the only kind of cattle present in the pasture that month— during the same period.

The usual amount of cattle in the studied pastures is a unity of cattle (rustic cow of 400 kg) per hectare, with a consumption of 10.5 kg per day per cow (FILLAT, 1980). So the consumption assessed per month was 32.55 g m-2.

3. Conclusions

The exclusions tested under seminatural conditions are statistically significant to studying the consumption of Acrididae in herbaceous communities. Three exclusions of 0.09 m^2 are enough in pastures with *Nardion* in the Pyrenees. This method may also be used in other more heterogeneous environments by increasing the number of exclusions.

The consumption of grasshoppers is related to temperature. However, the values of temperature recorded in the conventional weather studies are not appropriate to studying grasshopper activity. We must know microenvironmental temperature, that always reaches more extreme values.

With a diurnal average temperature of 21º C, grasshoppers consume daily their body weight in grass. The upper threshold of consumption seems to be placed between the 25-26º C (average diurnal temperature). The lower threshold has not been found with the experiments.

During some years, Acrididae densities in pastures above timberline are so high that consumption may be equal or even double to that of the cattle. The significance of this group in the nutrient recycling becomes particularly clear in the plant communities which have never been grazed (i.e. *Festuca eskia),* specially because the characteristics of grasshopper excrements facilitate the fast incorporation of nutrients into the soil.

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